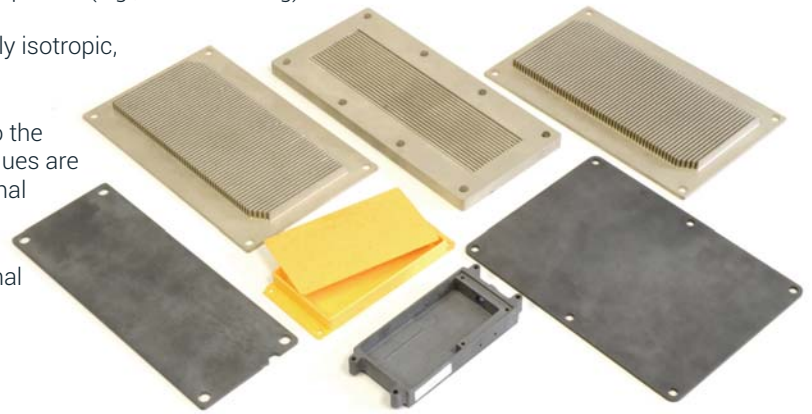




THERMAL MANAGEMENT MATERIALS

M Cubed Technologies, a subsidiary of II-VI Corp., is a leading provider of advanced metal matrix composites (MMCs) and reaction bonded ceramics to the semiconductor equipment, LCD equipment, wear, refractory, optics, defense, and thermal management markets. Development and manufacturing facilities are located in Connecticut and Delaware, and sales offices are based in the US, Korea, and Japan. M Cubed provides its customers with optimized turn-key solutions, starting with product design and analysis support, followed by material selection, fabrication and finishing. Key strengths of M Cubed include significant size and shape capability, large manufacturing scale, and tailorable material properties (e.g., CTE matching).

For Thermal Management, M Cubed offers a broad range of fully isotropic, high performance, engineered MMC and ceramic materials. In total, the materials provide a range of coefficient of thermal expansion (CTE) values. This range allows precise matching to the desired mating component. Moreover, thermal conductivity values are high, and in some cases exceed copper. All of M Cubed's thermal management materials are machineable (by cutting, grinding, lapping, and/or EDM), and support a broad range of product features including finned elements and components with internal cooling channels.



Metal Matrix Composites (MMCs)

Silicon carbide particle reinforced aluminum (Al/SiC) MMCs provide distinct advantages for thermal management applications. Since Al and SiC offer low density and high thermal conductivity, combining the two materials maintains these important material characteristics. At the same time, CTE can be tailored based on the SiC (CTE of 3 ppm/K) to Al (CTE of 23 ppm/K) ratio in the composite. Key attributes of M Cubed's Al/SiC MMCs are:



- Near and near-net shape manufacturing with investment, sand, and permanent mold casting
- Fully machinable, including direct threading
- Compatible with standard plating processes
- Greatly enhanced mechanical and thermal stability relative to traditional metals
- High toughness relative to ceramics
- Patent protected processes

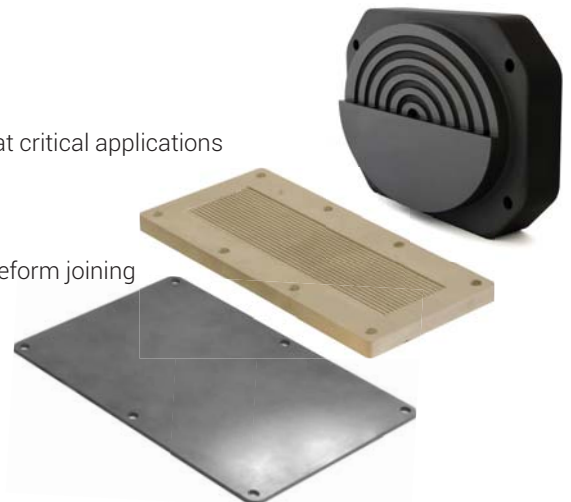
Reaction Bonded Ceramics

M Cubed provides multiple reaction bonded ceramic formulations to meet a broad range of design requirements and product applications. The following three reaction bonded formulations are available for thermal management. In addition, custom formulations are provided where required.

- Si/SiC (SSC-802): High thermal conductivity with CTE match to Si
- Si/SiC + Al (HSC-702): High thermal conductivity with CTE match to AlN
- Si/SiC + Diamond (Dymonite 100-60™): Ultra-high thermal conductivity for heat critical applications

Key attributes of the reaction bonded ceramics include:

- Near and near-net shape fabrication – near zero process shrinkage
- Complex shape capability with net-shape molding, green machining, and/or preform joining
- Ability to produce finned and internally cooled components
- Patent protected processes



THERMAL MANAGEMENT MATERIALS

Property Comparisons

Material	Description	Density (g/cc)	Young's Modules (GPa)	CTE (ppm/K- RT to 100°C)	Thermal Conductivity (W/mK -RT)
M Cubed ASC-303(Al/SiC-30p MMC)	Package/Heat Sink	2.8	125	14	160
M Cubed MMC-555(Al/SiC-55p MMC)	Package/Heat Sink	3.0	200	11	160
M Cubed SSC-802(Reaction Bonded Si/SiC)	Package/Heat Sink	3.0	380	2.9	185
M Cubed HSC-702(Reaction Bonded Si/SiC + Al)	Package/Heat Sink	3.0	330	4.4	200
M Cubed Dymonite 100-60™ (Reaction Bonded Si/SiC + Diamond)	Package/Heat Sink	3.2	650	1.5	540
Si	Semiconductor	2.3	112	2.7	156
GaAs	Semiconductor	5.2	90	6.5	54
GaN	Semiconductor	6.2	130
SiC(Single Crystal)	Semiconductor	3.2	420	3.1	450
Cu	Conductor/Metal	9.0	120	17	394
Al(6061)	Conductor/Metal	2.7	70	23	172
Kovar	Conductor/Metal	8.2	135	5.6	17
Invar 36	Conductor/Metal	8.0	150	1.7	11
Cu/W	Conductor/Metal	16-19	...	6-8	180-200
Cu/Mo	Conductor/Metal	9-10	...	7-9	190-210
Al ₂ O ₃	Insulator/Ceramic	3.9	360	6.5	20
AlN	Insulator/Ceramic	3.3	300	4.5	150-200
BeO	Insulator/Ceramic	2.9	330	7.6	250

REV 112614

www.mmmt.com